EUROPEAN COMMISSION

Community Research

Science and technology for sustainable energy

EU Research: Visions and Actions

SUMMARY

BACKGROUND

The EU strategy for sustainable development, endorsed by the Gothenburg European Council in June 2001, calls for the integration of social, economic and environmental policy objectives. Energy has deep and broad relationships with each of these three pillars. It is a precondition for economic development, essential for social well being and decisive for environmental performance. Growth in global energy demand is progressing rapidly, especially in the developing world, where two billion people are still without access to modern energy services. In the European Union, the satisfaction of energy needs is crucially linked to the security of energy supply, against a background of rising energy imports, and the commitments for reducing greenhouse gas emissions.

Energy research is a mainstay of any long-term energy policy. It has to provide scientific knowledge and technological options to make energy systems more efficient, affordable, accessible and environment friendly. Research and technology have to support energy strategies to facilitate the transition to a sustainable energy supply, through energy savings and the enhancement of renewable resources. Strategic objectives include the security of energy supply, the minimisation of the environmental impact and the competitiveness of European industry, in particular for emerging technologies expected to have a huge potential in liberalised energy markets.

One of the key messages of the European strategy for the security of energy supply is that today the EU depends on imports for 50% of its energy needs and this may rise to 70% in 2020, if no action is taken. No single energy option has the capacity on its own to fulfil all energy needs. There is a need for diversity and this has to be reflected in policy agendas and research priorities. Research has an essential role to play in enhancing and capitalising on the potential of all energy options, including nuclear fission and fusion.

STATE OF THE ART

The improvement of the energy systems and the promotion of new and renewable energy options can make a great contribution towards sustainable development. Research and development are at the foundation of continuous invention, adoption and improvement of **more energy-efficient systems, products and processes**. Even if fossil fuels still form the backbone of the energy systems, multidisciplinary research and technological advances have allowed them to increase efficiency and reduce environmental impact. Solid fuel power stations are currently capable of efficiencies of about 45%. Efficiencies of 50% to 55% are expected in the medium-term. Combined gas/steam cycle turbines has now achieved an efficiency of more than 55% and efficiencies of 60% - 65% are expected in the medium-term. Progress is being made in CO_2 sequestration technologies for post-combustion capture and storage. Co-generation, i.e. the combined heat and power generation, which currently accounts for nearly 10% of the electricity generation in the EU, is gaining ground.

New and renewable energy sources and related technologies are essential paths towards sustainable development. The European Union has set the target of doubling the share of renewables in energy consumption to 12% and achieving 22% electricity generation from renewable sources by 2010. Although renewable sources represent the fastest growing energy source in the world, they have still to overcome many technical and financial barriers to be able to penetrate markets. The integration of renewable and other distributed energy sources into the existing systems represents an enormous technological challenge. A European Directive adopted in 2001 offers a Community framework to promote renewable energy sources in the internal electricity market.

The European Union accounts for 75% of the World installed capacity for **wind energy** production. Public support frameworks and private sector competition led to rapid technical progress

that has boosted innovation, performance and competitiveness. **Solar energy systems** are experiencing considerable growth, albeit admittedly from a very low base. Market niches are being explored by solar thermal energy. Research tries to enhance opportunities offered by **bioenergy**, which can directly replace all forms of fossil fuel vectors, either solid (e.g. coal by wood chips), gaseous (e.g. natural gas by biogas) or liquid (e.g. gasoline or diesel by bio-ethanol or biodiesel). **Fuel cells**, electrochemical devices that produce energy in a much more efficient and clean way than conventional combustion, have an untapped potential. In the long-term, fuel cells and **hydrogen** are expected to form an integral part of the energy supply where hydrogen together with electricity would be the major energy carriers. **Socio-economic and strategic research** contributes to the long term shaping of the energy systems and the promotion of clean energy options.

Nuclear fission energy, which today provides 35% of the electricity produced in the EU, offers a clean substitute to fossil fuel combustion, but it generates radioactive waste, a small percentage of which is highly radioactive, remaining hazardous for over ten thousand years. The main option for managing this waste is deep disposal in geological formations and research in this field is well advanced. Decisions on disposal also involve social aspects. Research has to provide options for management on which a consensus can be reached. This is a crucial issue for the future of nuclear energy, together with the economic viability of new generations of power stations and the prevention of nuclear proliferation.

Fusion involves the fusing together of light atoms (such as hydrogen) and is the ultimate source of most energy used by mankind because it powers the sun and all the other stars. Reproducing the energy of the stars on Earth has long been a vision, now coming close to reality after several decades of intense efforts. It is a long-term option that could provide a substantial contribution to energy supply in the future. The integration of all EU activities in this field into a single, co-ordinated programme has contributed to Europe achieving a position of excellence. The success of ground-breaking experiments such as JET (Joint European Torus) and other smaller facilities, has led the EU and its international partners to design a reactor-scale device, known as ITER (International Thermonuclear Experimental Reactor), the next step towards fusion power.

RATIONALE AND OBJECTIVES

Clean, safe, reliable, competitive and affordable energy supply can only be guaranteed by a combination of independent environment-friendly energy systems. Clean technologies are essential for improving the environmental performance of the energy sector. They can contribute to the reduction of energy consumption by increasing the efficiencies of both energy-supply and energy end-use systems. They can impact the choice of fuel used for energy production and enable the decrease in emissions through removal of pollutants from combustion gases.

The time-scale associated with the development of energy technologies is long. Several years, even decades, are often needed before new technologies evolve through the energy innovation chain and reduction and disruption of funding can be disastrous.

Within the range of renewable energy options, significant progress has already been made in the field of **wind energy**. The costs for electricity generation from **photovoltaics and solar thermal systems** are significantly higher than those of conventional fuels. The investment cost of photovoltaics has to be reduced by a factor of more than four. Main barriers for solar thermal technologies include physical constraints and high installation and production costs. Intensive research is also needed to realise the potential of **biomass and biofuels**, given the very ambitious EU target in this field. In the framework of the aim for doubling the share of renewables by 2010, bioenergy should in fact contribute 7% to total consumption.

Hydrogen is highlighted, in parallel with electricity, as the energy carrier of the future. Used in fuel cells, it combines with oxygen electrochemically, yielding electric current, heat and water. **Fuel cells** represent a paradigm shift in power generation for transport, stationary and portable applications; they face however substantial market entry barriers. They are not yet technically mature and, even if hydrogen is the long-term choice, there is still debate about the various options and transition paths to make a leap forward. The

Solar Test platform in Almeria, Spain (Courtesy of Ph. Schild)

Psitalia biogas plant in Athens, Greece (Courtesy of Biocogen project)

FOR FUTURE RESEARCH

development of a hydrogen economy, with hydrogen produced from renewable energy sources, is a long-term objective of the EU research and development agenda.

The expected integration of this broad range of technologies during the coming years will move Europe towards the **Distributed Energy Resources** model, which has a large potential to deliver new energy services and remove the geographic constraints on power transmission and distribution. This pattern is expected to increase competition and enhance quality, reliability, security and safety of energy supply.

Socio-economic and strategic research sheds light on the most cost-effective and sustainable energy options, establishes medium to long-term scenarios (from 2010 to 2100), quantifies externalities (socio-environmental damages) and provides a benchmark of energy-related technology regulations.

Considering all energy options is essential for EU research. The Euratom treaty stipulates that research and development in the field of **nuclear energy** are a European responsibility. Research on the management of **radioactive waste** and **radiation protection** is vital and has to be accompanied by social mechanisms for risk governance. Coordination is also needed to address the risk of loss of national nuclear expertise, which will be needed for the safe continued operation of the nuclear reactors and waste management.

Nuclear fusion constitutes a frontier technology. The primary fuels for fusion are abundant and easily available. It would not expose the public to any major risk of accidents or produce radioactive waste that would be a burden for future generations. Fusion research spans various disciplines and relies on multiple innovations and cutting-edge developments in many scientific and engineering areas, leading also to near-term spin-offs. Progress has made it possible to design, in ITER, a fusion plasma which will deliver ten times more power than is needed to reach the fusion temperatures.

ONGOING ENERGY RTD ACTIVITIES

Energy constitutes one of the foundations of the European Union. The European Union grew out of the Economic Community, the Coal and Steel Community (ECSC) and the European Energy Atomic Community (Euratom). Energy is the only research theme to straddle two treaties. Current research activities are included in the 1998-2002 Framework Programme of the European Union for Research, Technological Development and Demonstration and the 1998-2002 Framework Programme of the European Atomic Community for Research and training activities.

Research on Non-Nuclear Energy addresses the objective of advancing towards more secure and sustainable energy systems and services and includes two key actions: the **development of cleaner energy systems** and the **improvement of economic and efficient energy technologies**. More specifically, current research actions deal with energy production from renewable sources, such as photovoltaics, wind energy, solar-thermal, geothermal, tidal energy and biomass, development of cleaner energy from fossil fuels, research into hydrogen and fuel cells, and improvement of energy systems, energy storage and distribution.

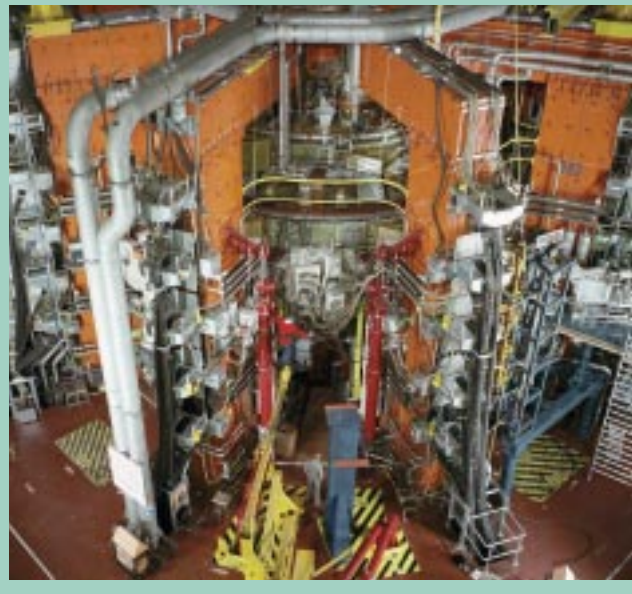
Research activities under the Euratom Treaty aim at exploiting the full potential of nuclear energy. Research activities on **fission** focus on the safety of European nuclear installations and of the fuel cycle, as well as the safety and efficiency of future systems. Actions on **radiation protection** addresses the protection of workers and the public from ionising radiation and the development of a safe and effective management and final disposal of radioactive waste. Other activities in this field explore more innovative long-term con-

Hydrogen powered car (Courtesy of BMW)

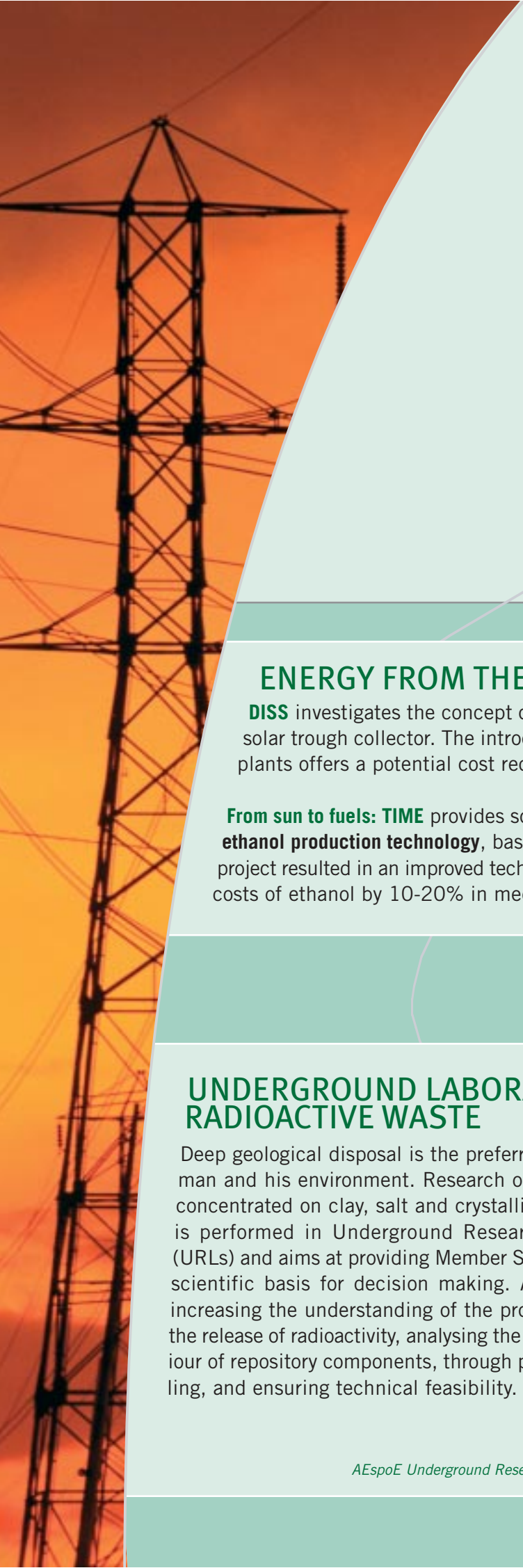
Glove box for actinide research (Courtesy NRG, NL)

cepts or contribute towards the maintenance of a high level of expertise and competence on nuclear technology and safety in Europe.

Fusion research activities focus on demonstrating the capability of fusion to contribute in the second half of the century to the emission-free, large-scale production of base-load electricity. Theoretical work and experimental studies on the existing devices world-wide, in particular on the European JET, have established the scientific and technical readiness for the construction of a project of the next generation. World-wide collaboration on fusion energy research has progressed to the detailed engineering design of ITER, with the objectives of operating in conditions relevant to energy production. The successful completion of the ITER design makes it possible, in line with the reactor orientation long-term objective of the Community research on fusion, to take a decision about its realisation during FP6.



The JET plant during the transformation operations



ENERGY FROM THE SUN

DISS investigates the concept of direct **super-heated steam generation** using a parabolic solar trough collector. The introduction of this technology into concentrated solar power plants offers a potential cost reduction for electricity generation of up to 25%.

From sun to fuels: TIME provides solutions for the development of a new and cost-effective **ethanol production technology**, based on lignocellulosic residues and dedicated crops. The project resulted in an improved technology, which could be expected to reduce the production costs of ethanol by 10-20% in medium-to-long term.

UNDERGROUND LABORATORIES FOR THE DISPOSAL OF RADIOACTIVE WASTE

Deep geological disposal is the preferred option for **isolating high level radioactive waste** from man and his environment. Research on suitable geological formations in Europe is primarily concentrated on clay, salt and crystalline rock formations. An important part of this research is performed in Underground Research Laboratories (URLs) and aims at providing Member States with a solid scientific basis for decision making. Activities aim at increasing the understanding of the processes affecting the release of radioactivity, analysing the long-term behaviour of repository components, through predictive modelling, and ensuring technical feasibility.

AEspoE Underground Research Laboratory,Sweden

FUERO

Courtesy of PSA

FUERO is a cluster of projects developing components and systems for **fuel cell vehicles**. It aims at accelerating the introduction of fuel cells for transport by co-ordinating RTD on fuel cell stacks, fuel processors, components and systems. It is promoting co-operation among automotive industry, university partners and research organisations to overcome these high technical and non-technical barriers. In the short term, the cluster is expected to deliver typical vehicle fuel cell system requirements, as well as actual hardware. In the longer term, the successful components will be integrated into fuel cell systems for vehicles and demonstrated in prototypes or small fleets. The FUERO umbrella project sets specifications for fuel cells and components developed in the cluster. It will help define testing and demonstration programmes for components and complete vehicles.

EXTERNE

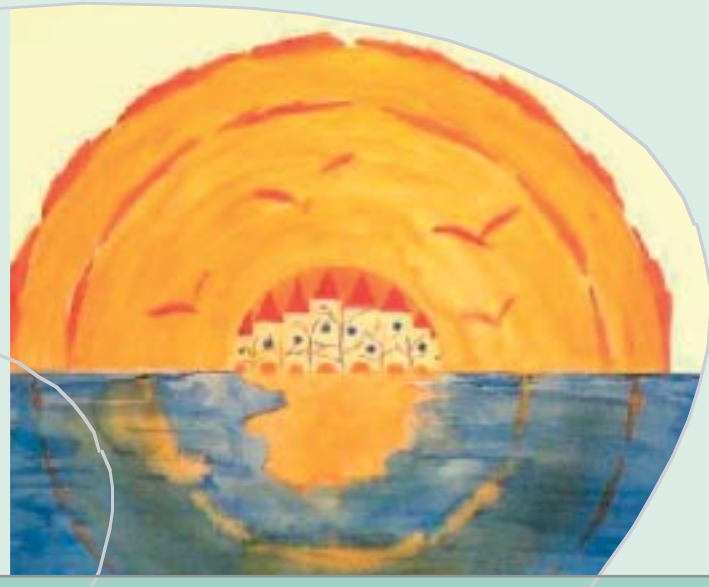
The EXTERNE project is the first research project to put plausible financial figures against **damages resulting from various forms of electricity generation** (fossil fuels, nuclear and renewables) for the entire EU. It has proven that the cost of producing electricity from coal or oil would double and the cost of electricity production from gas would increase by 30% if external socio-environmental costs, such as damage to the environment and public health, were taken into account. Wind and hydro energy present the lowest external costs. Nuclear power involves relatively low external costs due to its small contribution to global warming and its low probability of accidents in the EU power plants. The cost of electricity generation, currently about EUR 0.04 per kWh, should be reduced, with the enhancement of environmentally friendly options, presenting low external costs.

EUROPEAN ADDED VALUE

European Union energy research focuses on the actions with the greatest European added value. They include actions with high-level research capability scattered all around Europe (e.g. renewable energy sources, energy efficiency in buildings), cases of common concern for many Member States (e.g. nuclear waste management), or projects which are too large in scale for any single Member State (e.g. the development of nuclear fusion). The creation of the European Research Area, introducing a paradigm shift to address the fragmentation and the duplication of research efforts, is expected to enhance the European added value of energy research.

European support should concentrate on those topics where it is essential to have a critical mass sufficient to make progress and generate new knowledge and industrial activities. It is necessary for the European Union to establish a genuine networking of research actors, policy makers and projects, whether they are national or regional, undertaken by the public sector or by industry. Initiatives in the field of energy research and innovation can benefit from the new direct support mechanism for co-operation proposed by the Commission. This is expected to result in the mobilisation of a mass of resources able to provide a genuine structuring effect to European actions. Within the framework of the European Research Area, “stakeholder partnerships” bringing together production companies, equipment and component manufacturers, end users, academia and standardisation organisations, in the form of integrated projects and networks of excellence, can accelerate the cost-effective development and deployment of sustainable technologies.

RTD PRIORITIES FOR SUSTAINABLE ENERGY SYSTEMS



Courtesy of Voula Mega

The European Community Framework Programme for 2002-2006, an essential instrument to structure the European Research Area, includes seven major priority themes, defined after wide consultations with the Institutions and the scientific and industrial community. One of them is **sustainable development** and includes activities on **climate change, energy and transport**.

Underlying socio-economic aspects and pre-normative research are given special attention. Research thrives only if it is adopted by industry and if its usefulness is recognised by public opinion. Innovation is crucial. The role of small and medium-sized enterprises and technology company start-ups is being given importance.

Energy research includes activities for both the short and long term. The short-term actions target the efficient use of energy, as well as the validation and demonstration of new and renewable energy technologies and their integration into existing energy systems in combination with conventional technologies. They also include activities on alternative motor fuels.

Longer term actions aim at preparing the conditions for the development of alternative sources and transformation methods most likely to break away from the present energy supply system, which is strongly dependent on fossil fuels, in particular in relation to transport and the production of electricity and heat. The actions cover fuel cells and their applications, new energy carriers and especially hydrogen, new and advanced concepts in renewable energy technologies which have a large potential, primarily biomass and photovoltaics, and sequestration of CO_2, associated with cleaner fossil fuel systems.

Research on advanced materials for the production and storage of energy focuses on emerging technologies, such as nanotechnologies. Actions

Courtesy of Timberjack

cover the development of new intelligent materials incorporating multi-functionality, intelligence and autonomy. Such materials for very high temperatures are expected to improve the efficiency of energy production.

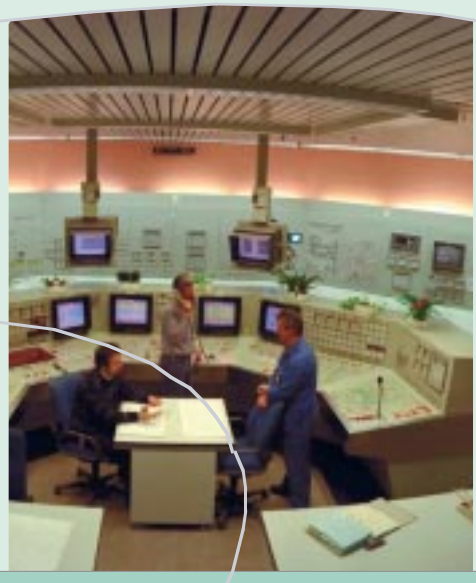
Evaluating the costs and benefits of the various energy options is difficult. Research will have to provide the scientific and technological elements enabling decision-makers to make pertinent choices towards a sustainable future.

Future scientific and technological needs have also to be anticipated and a mechanism has been provided, in the Framework Programme, to address the challenges related to the frontiers of knowledge and unforeseen developments. The dialogue between science and society is also being reinforced, in order to reconcile technological progress and social values.

Injection of CO_2 into a deep salt-water reservoir (Courtesy of Statoil)

(Courtesy of Ph. Schild)

RTD PRIORITIES IN THE NEW EURATOM PROGRAMME



A nuclear power plant control room

A cut-away drawing of the ITER tokamak

The principles proposed for the new EURATOM programme emphasise the concentration on a limited number of strategic objectives to strengthen collaboration between Member States. Major priorities concern **nuclear waste management** and **radiation protection**, which are critical for the continuing use of nuclear energy for electricity production. Nuclear power stations currently in operation will continue to function for decades and this calls for the large-scale implementation of long-term technical solutions for waste management. There is significant public and private European research effort on the development of technologies for the treatment and storage of nuclear waste. The action of the Union in this field makes it possible to strengthen and ensure the consistency of the strategies adopted by waste management agencies and organisations. Moreover, the debate on the structure of our energy supply after 2020 may necessitate concerted research effort at the international level on a new generation of fission reactors.

Fusion research is now on the cusp between two generations of experimental installations. Research activities in fusion physics and plasma engineering, as well as in fusion technology, are necessary for the continuation of the development of fusion by magnetic confinement towards its ultimate goal, electricity production. The design of ITER has been made in a global-scale collaboration, and the negotiations on its construction bring together the international partners. ITER constitutes an essential step towards the demonstration of the scientific and technological feasibility of fusion power production. The devices in the generation after ITER will be prototypes for commercial fusion power stations. Socio-economic research has already indicated that future fusion power stations should be economically competitive. Further investigation of public awareness and acceptability of fusion power will be undertaken in FP6.

KI-NA-20-485-EN-C

The role of research and technological development in advancing towards **sustainable (clean, secure, competitive and affordable)** energy in the European Union is crucial.

The EU imports half of the energy it consumes and this figure is expected to reach two thirds by 2020, if present trends continue. No single energy option has the capacity to fulfil all the needs of the EU. Diversification is necessary and has to be reflected in policy agendas and research priorities. Enhancing and realising the potential of all energy options and capitalising on all opportunities is essential.

Renewable energy sources, fuel cells, hydrogen as an energy carrier, improved energy efficiency, clean fossil-fuel technologies including CO_2 sequestration, improved methods of energy management, transmission, storage and system integration, nuclear fission and fusion can all contribute towards a sustainable energy future. Energy research and development should keep **all** options open and continuously raise the bar of excellence.

Price (excluding VAT) in Luxembourg: 10 EUR

OFFICE FOR OFFICIAL PUBLICATIONS
OF THE EUROPEAN COMMUNITIES
L-2985 Luxembourg

ISBN 92-894-4350-2